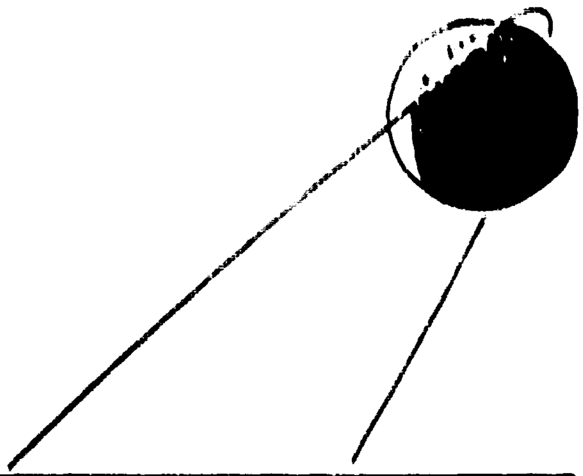
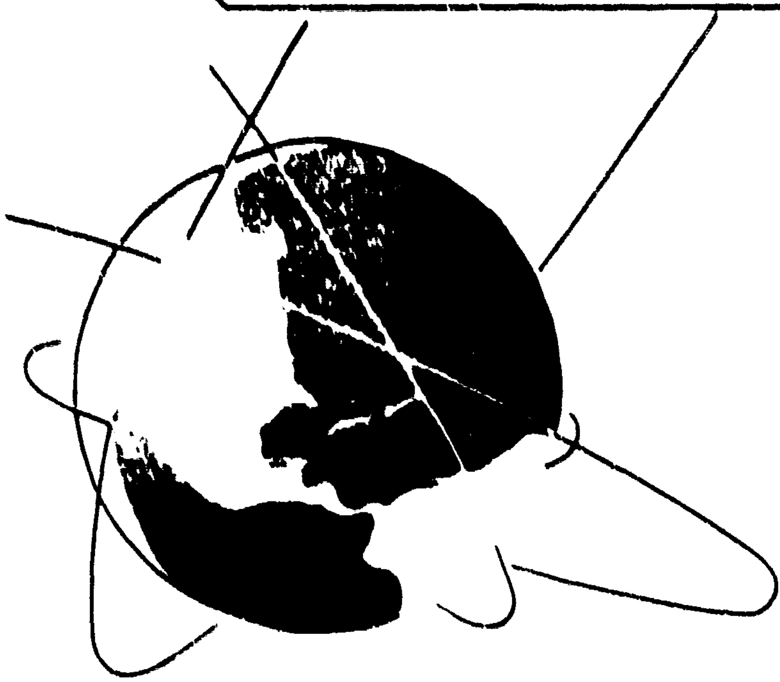


GROUND IMPACT SHOCK MITIGATION DRIVE-OFF SYSTEM DEVELOPMENT CARGO TRUCK, 3/4-TON M37

BY

DAVID G. WIEDERANDERS

EMRL TR 1000 JULY 1967



ENGINEERING MECHANICS RESEARCH LABORATORY
THE UNIVERSITY OF TEXAS · AUSTIN, TEXAS

28

GROUND IMPACT SHOCK MITIGATION DRIVE-OFF SYSTEM DEVELOPMENT
CARGO TRUCK, 3/4-TON M37

by

David G. Wiederanders

U. S. ARMY NATICK LABORATORIES

AIRDROP ENGINEERING LABORATORY

Project No. 1F121401D195

CONTRACT DA 19-129-AMC-582(N)

ENGINEERING MECHANICS RESEARCH LABORATORY
THE UNIVERSITY OF TEXAS
Austin, Texas

July 31, 1967

PREFACE

The results reported here were obtained in response to a request from the U.S. Army Natick Laboratories. It was requested that the Engineering Mechanics Research Laboratory undertake the development of a cushioning system for an M37 3/4-ton truck which would allow the vehicle to be driven off after airdrop at impact velocities ranging from 15 to 30 fps. Field observations had indicated that impact velocities during actual airdrop were varying over this range.

The cushioning system is required to protect the vehicle from damage during the impact, while at the same time providing the drive-off capability. Also, additional flexibility in airdrop operations is provided if the vehicle can be driven off without having first been dropped.

Details of the test program which culminated in the achievement of all these objectives are given in the report.

The study was suggested by Mr. Harry Freeman of the Natick Laboratories, and he also assisted in working out some of the test procedures.

E. A. Ripperger
Director
Engineering Mechanics Research Laboratory
The University of Texas
Austin, Texas

July 31, 1967

TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

Eight drops involving the M37 3/4-ton truck have been made in the velocity range from 15 to 28 fps, at design accelerations ranging from 17.5 to 30g. The cushioning system used for each drop is described and the damage sustained by the vehicle is discussed. It is concluded that the cushioning system developed in this series of tests provides adequate protection in the velocity range investigated and also provides a drive-off capability for the vehicle.

The final cushioning system is described in detail and its effectiveness under some of the conditions that might be encountered in actual field drops is evaluated.

INTRODUCTION

The delivery of military equipment and supplies for deployment in the field has long been a problem to the military logistics division, which must find a workable solution to these problems. The major problem faced is the element of time. This problem is obvious if the delay of critically needed equipment is considered. Another problem connected with this situation is that the equipment must be delivered in proper operating condition if it is to be useful in its tactical employment. A third problem is the time required for the deployment after the equipment is delivered to the critical area.

The problem of rapid delivery to the critical area has become less of a problem with the advent of the airdrop of equipment and supplies. Coupled with the developments in the speed of airdrop has been the increased protection provided the equipment to be air dropped. This increase in protection has been extended considerably since the introduction of paper honeycomb as a cushioning material.

The problem of expedient deployment of the equipment has, however, remained a problem throughout the development phases concerned in the solutions to the two previously mentioned problems. One of the major points involved in the deployment problem is the time required to unpackage the equipment which has been airdropped. Hence, if this required time can be decreased substantially or even eliminated, the military advantages gained will be significant.

It was in response to this problem and specifically to the problem involving the M37 3/4-ton cargo truck that the development program described here was undertaken. It is also expected that the results of this study will provide guidance for development of drive-off cushioning systems for other vehicles.

PROCEDURE

The approach employed was to begin with the cushioning system which had been recently developed for this vehicle[1] and to modify this basic system to provide the drive-off capability desired. Some initial changes were made however, to allow for the specified impact velocity range of 15 to 28 fps.

The truck used for this series of drops was an M37, 3/4-ton, 4 × 4 Cargo Truck supplied by the U.S. Army Tank-Automotive Center under arrangements made through the U.S. Army Natick Laboratories. This vehicle was issued initially for use in the test series involving the high velocity dropping of military vehicles.[1] Under this series, the truck was dropped seven times from heights up to 45.5 feet.

The truck was employed in the "as received" condition except for the following modifications:

1. Windshield removed
2. Cab removed
3. Outside mirror removed
4. Lifting wheel plates installed
5. Three accelerometers, one each installed on the winch, the engine, and the rear frame cross member.

The first four modifications were made to allow room for the lifting apparatus, and the last to provide acceleration data for comparison with the design acceleration and for possible correlation with observed damage.

Drop Program

The program followed in this development series called for the first drop to be made using the cushioning system developed for the high velocity drops of this vehicle. In subsequent drops, the system was to be modified to incorporate changes in the system which were shown to be necessary or desirable by the results of previous drops. This allowed more emphasis to be placed on perfecting the drive-off capability rather than seeking the solutions to problems that are usually present in any newly-designed cushioning system.

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1. Wiederanders, D.G., W.L. Guyton, and E. A. Ripperger, *Ground Impact Shock Mitigation Cargo Truck, [illegible]-Ton [illegible], EMRL TR 1011*, December 1966, Engineering Mechanics Research Laboratory, The University of Texas, Austin

After thorough study of the problems involved in the drive-off of a vehicle of this type and with a background of experience gained in the development of other cushioning systems for this vehicle,[2] it was decided to use a system of honeycomb ramps to provide the drive-off function. See Fig. 1

Problems Encountered

Some of the problems encountered were due particularly to design shortcomings of the vehicle itself. Among the problems were:

1. Difficulty in cushioning the engine adequately.
2. Weak center cross members in the frame assembly.
3. Insufficient area under the bed and rear of the truck to cushion effectively.

During the test series involving the high velocity dropping of this vehicle, loadspreaders were used to solve the last two of these problems. The initial cushioning system in the development of the drive-off capability was a slightly modified version of the final system used in the high velocity tests. See Fig. 2 and Table 1 for details of this system.

It became evident however, after the second drop that the center loadspreader made the development of a drive-off capability very difficult. Consequently, it was eliminated for the remainder of the test series. Omission of the front and rear loadspreaders was also considered but it was finally decided that they had to be retained in the cushioning design. These loadspreaders were however, redesigned to allow for easy fabrication from generally available materials. See Fig. 3 for details.

Lifting Rig

The M37 truck used for this test series was rigged for drop by attaching lifting plates and shackles to each of the wheels. To facilitate the lifting and leveling of the vehicle, chains were attached to one end of each of four slings. One of these chains was passed through each shackle and hooked back on itself. This allowed for quick adjustment of each wheel independently to achieve a level attitude of the vehicle.

The four sling ropes were separated by spacer beams to prevent

2. Covington, Clarke and Richard Shield, *Fragility Studies, Part II, Cargo Truck, M37, 3/4-Ton*, April 1960, Structural Mechanics Research Laboratory, The University of Texas, Austin.

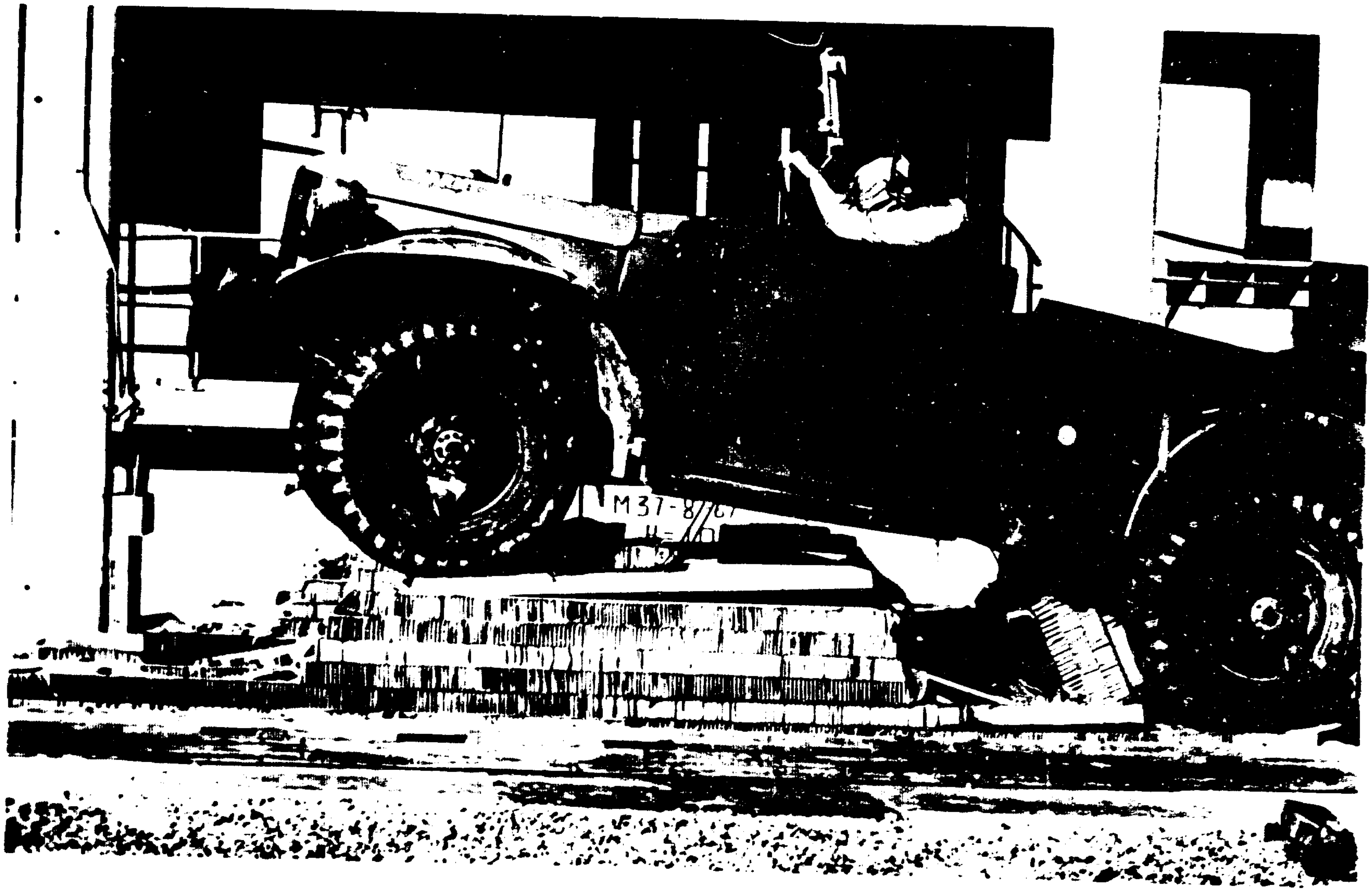


Fig. 1 Drive Off using Ramp System

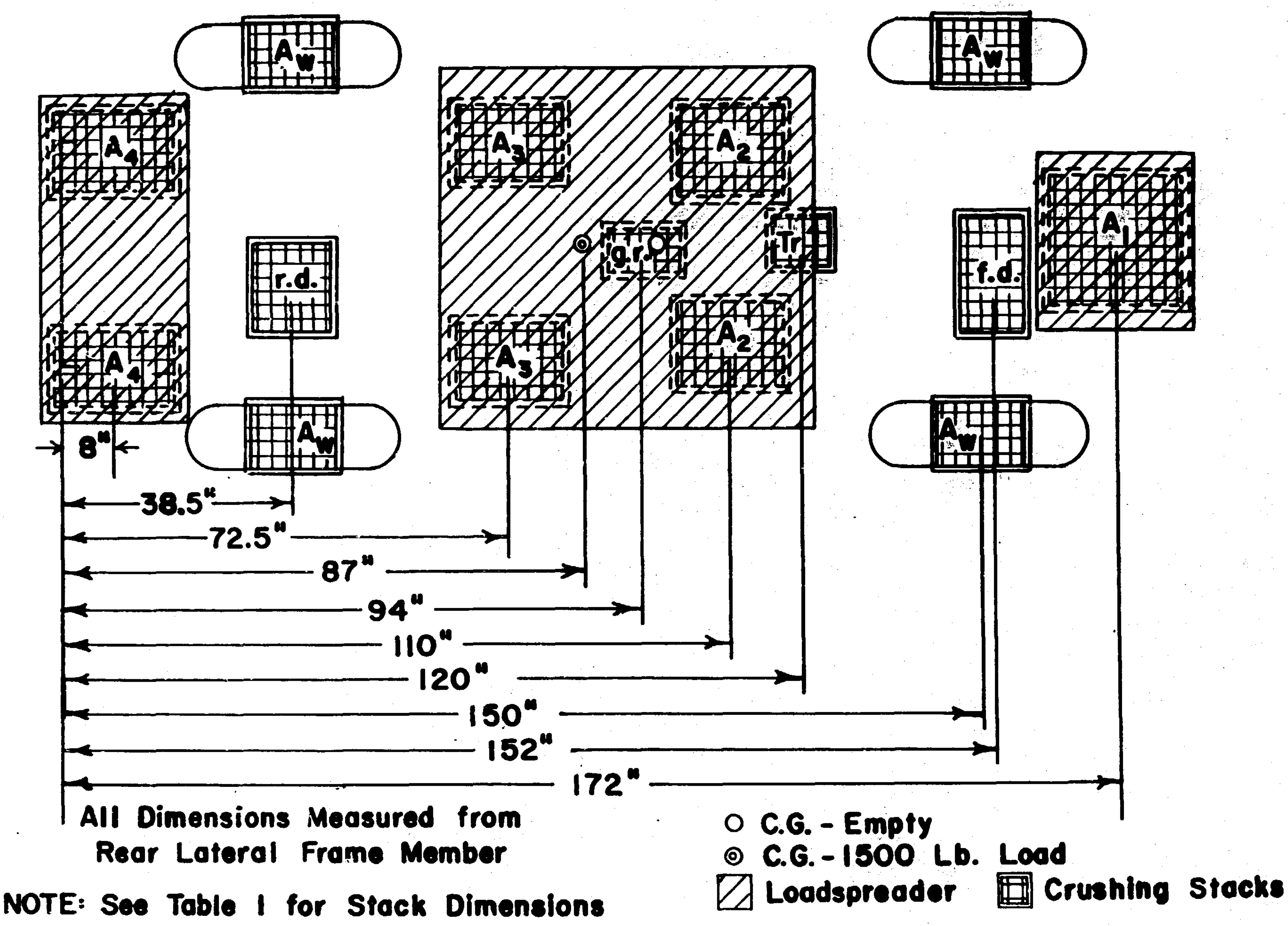


Fig. 2 Cushioning System for M37-8-67 and M37-9-67

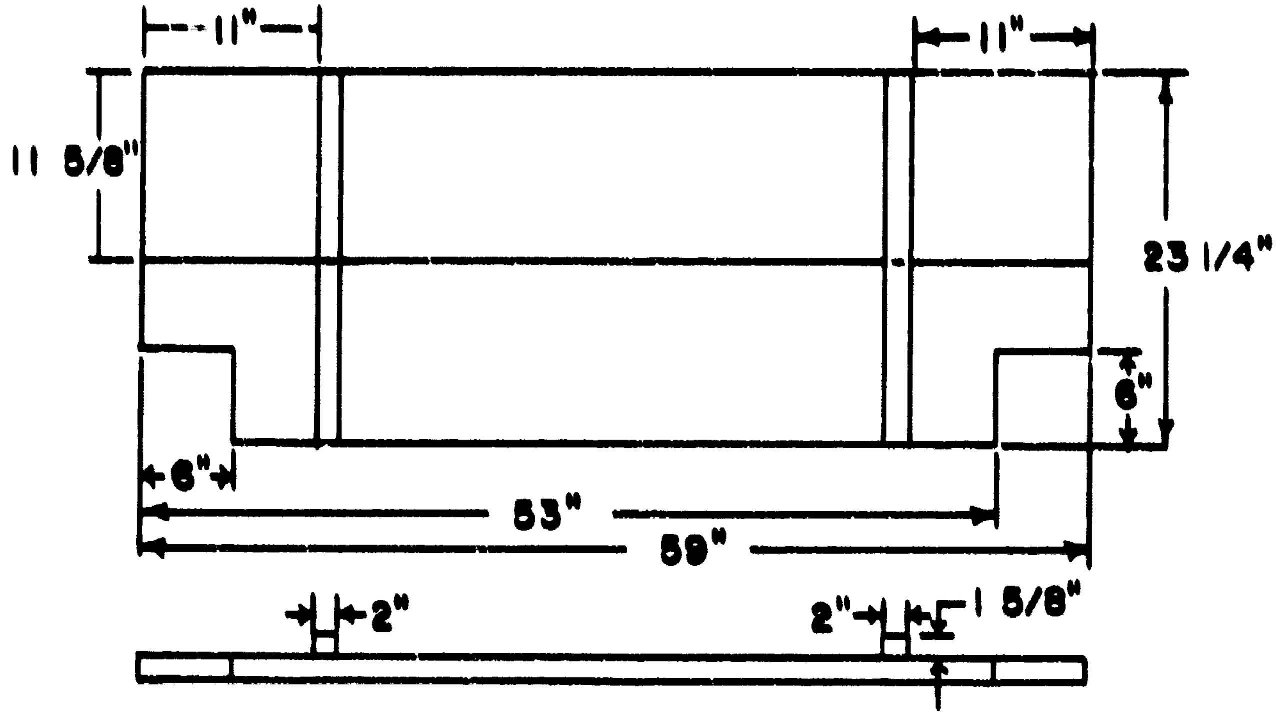
TABLE 1

Drops M37-8-67 and M37-9-67

Design Acceleration 30g

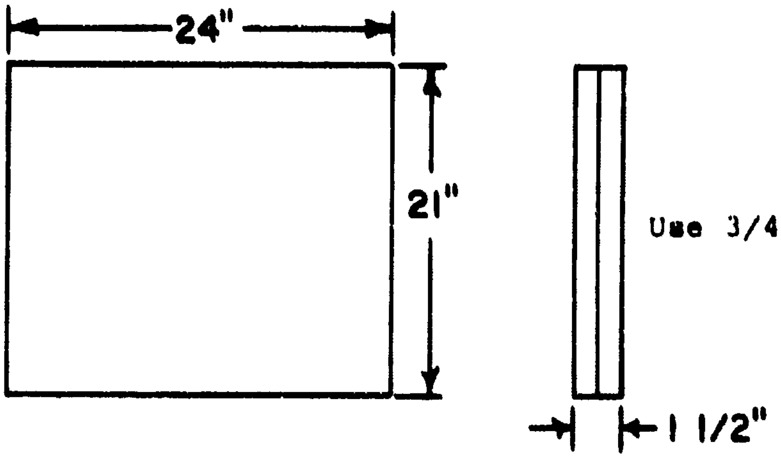
Position (See diagram)	Stack Area	Dimension W × L	Height
A_1	4.50 ft^2	2.0'×2.25'	6 in.
A_2	2.57 "	1.5'×1.71'	6 "
A_3	2.65 "	1.5'×1.75'	6 "
A_4	2.59 "	1.4'×1.85'	6 "
Tr (transmission)	.90 "	.95'× .95'	6 "
g.r. (gear reducer)	1.36 "	1.0'×1.36'	6 "
f.d. (front differential)	2.07 "	1.15'×1.80'	6 "
A_w	1.33 "	1.0'×1.33'	6 "
r.d. (rear differential)	2.07 "	1.5'×1.38'	6 "

Total Height of System including Cushioning Stacks = 69.5 in.



Use 2×12 stock lumber

Rear Loadspreader



Use 3/4" plywood

Front Loadspreader

Fig. 3 Simplified Loadspreaders used for all Drops after M37-9-67

damage to the vehicle, and attached to a large lifting shackle. This shackle was engaged by a helicopter hook which was released for the drop by the Fastax Camera timing control. The entire rigging is shown in Fig. 4.

Platform

An 8 × 16 ft. plywood platform was designed and built, essentially to the specifications for the combat expendable platform described in TM 10-500-11. This platform was used for the seven drops of the high velocity test series involving this same vehicle and also for the five drops of the series involving the 105mm Howitzer. During these drops, it performed very well and has been damaged only slightly by the twenty drops in which it has been used.

Honeycomb

The cushioning material used throughout this series was 80-0-1/2 paper honeycomb purchased directly from the manufacturer. A honeycomb evaluation test series involving stacks in excess of 12 inches in height provided the values of average crushing stress and energy dissipation characteristics which were used for the test program. These values were found to be slightly lower than the values obtained for single pads. This seems to be a consequence of crushing always occurring at the weakest section regardless of which pad contains the weakest section. On the other hand, every cell of a single pad must start collapsing at the instant of impact.

Instrumentation

Accelerometers were mounted on the vehicle in the following positions: winch housing, engine, and rear area.

In addition to acceleration records which were recorded by a magnetic tape system, high-speed motion pictures were made of all drops. These pictures were studied for an indication of the efficiency of the cushioning and for clues as to what changes should be made to improve the performance of the system.

Prior to and at the completion of each drop, documentary photographs were also made. After each drop, the vehicle was carefully examined for any visible damage or possible future problem areas.

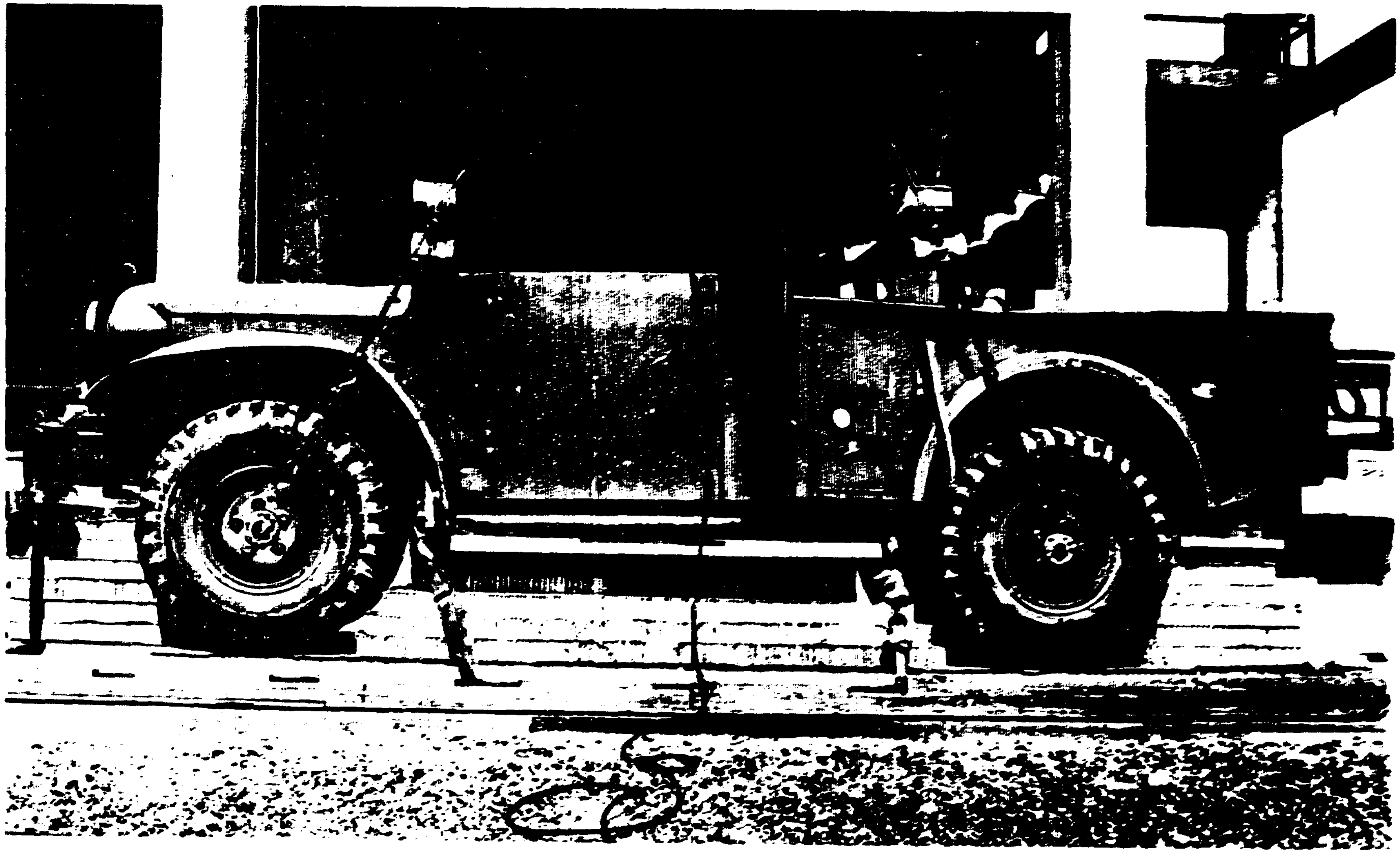


Fig. 4 Rigging for Lifting the M37 Truck

SUMMARY OF DROP PARAMETERS AND DAMAGE OBSERVED

M37-8-67; Height 10 ft.; Acceleration 30g.

The initial drop of this development series was made using the cushioning system designed and tested for the high velocity dropping of this vehicle. To this basic system was added a ramp system which, it was hoped, would allow the truck to be driven off of the cushioning system after impact.

The design impact acceleration for this cushioning system was 30g and with the exception of stack height modifications to allow for the decreased impact velocity, the cushioning system was the same as that used for drop M37-7-67.[1] See Fig. 2 and Table 1.

The cushioning system crushed uniformly, but only to about 50 percent. As a consequence, there was insufficient weight supported by the wheels after impact to provide the traction needed to drive the truck off of the cushioning system. After additional material was placed under the wheels, the truck had sufficient traction and was driven off of the cushioning system.

M37-9-67; Height 10 ft.; Acceleration 30g.

The second drop of this development series was made again using the cushioning system developed in the test series involving the high velocity dropping of this vehicle, as shown in Fig. 2 and Table 1. The buildup stacks under the wheel crushing stacks were eliminated to provide sufficient traction to allow the vehicle to be driven off of the cushioning system.

The system performed well crushing uniformly to 55 percent. After the documentary pictures were completed, the truck was backed off of the cushion system. Although the drive-off phase was accomplished without difficulty, it appeared that the large central loadspreader incorporated in this system would cause problems in actual field usage. Therefore, for the remaining drops of the series, the cushioning system was changed to eliminate this loadspreader.

M37-10-67; Height 10 ft.; Acceleration 20g.

In the design of the cushioning system for this drop, an effort was made to simplify the loadspreaders. The resulting

[1] *Ibid*, p. 2.

cushioning system shown in Fig. 5 eliminates the need for the large central loadspreader by combining the cushioning stacks which were previously under this loadspreader into two major stacks which were placed under the frame on either side of the truck.

The two loadspreaders which were retained were redesigned to allow for simple fabrication from commercially available materials. This new system also used a reduced area to allow for a design impact acceleration of 20g rather than the 30g design used for the high velocity drops.

Due to an error in calculating the required stack areas to be used under the rear loadspreader, the desired crushing was not obtained. Even though the maximum crushing was not obtained, the truck was driven off of the cushioning system after the rear crushing stacks and loadspreader had been manually pulled out of the way by two men.

M37-11-67; Height 10 ft.; Acceleration 17.5g.

For this fourth drop of the series, the cushioning system was again redesigned to improve the drive-off capability.

This new cushioning design involved a reduction in the cushioning area to provide a 17.5g design impact acceleration and a reduction in cushioning stack height to provide for an additional reduction in cushioning volume. See Fig. 5. It was hoped that with these changes incorporated, the percentage of crushing necessary for drive-off could be obtained throughout the impact velocity range being considered.

In redesigning the cushioning system, provision was made for an additional crushing pad under each wheel to insure that the truck would not be damaged if the new design cushioning volume proved insufficient. This pad was partially crushed and as a consequence, the full weight of the vehicle was not supported by the wheels after impact. Drive-off presented no difficulties, however. This indicates that the truck can be driven off of this cushioning system even if crushing to 70 percent strain is not obtained.

M37-12-67; Height 10 ft ; Acceleration 17.5g.

For the fifth drop of the series, the additional crushing pad was deleted and the drop was made with the truck tilted 15 degrees to the horizontal, with the left side of the vehicle low.

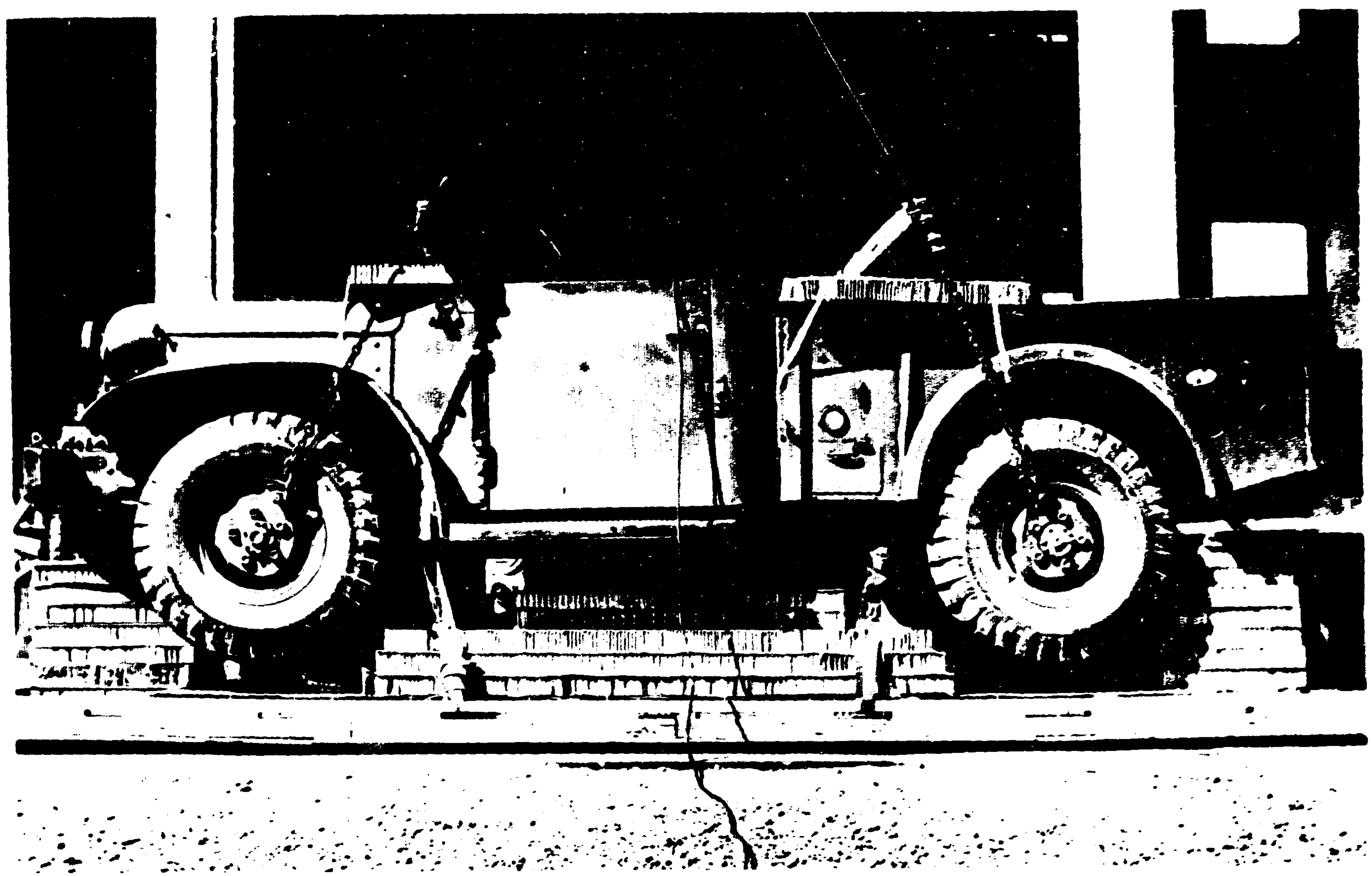


Fig. 5 Final System with Ramps

This tilt was included to provide one of the extreme conditions likely to be encountered under field conditions.

The system performed well. A uniform crushing which was estimated to be 90 percent of the crushing stack height was observed. This extremely high estimated percentage of crushing is based on the final distance between the loadspreader and the top of the build-up stack. Actually the build-up stack crushed some under the crushing stack. There was no truck damage and the drive-off phase was accomplished without problem.

M37-13-67; Height 10 ft.; Acceleration 17.5g.

This drop was made with the truck and system tilted 8 degrees to the horizontal with the front end high as shown in Fig. 6 As mentioned previously, this was done to more closely simulate actual field conditions. During this drop, the left rear engine support was broken off the bell housing. As a consequence, the truck could not be put into gear and driven off the platform. This failure was probably not caused by this one drop alone, but resulted from the accumulated effects of the twelve previous drops.

Although the damage to the truck prevented drive-off, it seems very likely that had the damage not occurred, drive-off could have been accomplished. Crushing of the cushioning was about the same as in the previous drop.

M37-14-67; Height 10 ft ; Acceleration 17.5g.

This drop was a repeat of the conditions for M37-13-67 and was made after the truck had been repaired. See Fig. 6. Additional precautions were taken by supporting the engine with nylon webbing straps. This had not been done for the 13 previous drops.

Crushing appeared to be about the same as in the two previous drops. No damage to the vehicle was observed and the drive-off phase was completed without difficulty.

M37-15-67; Height 3.5 ft.; Acceleration 17.5g.

The previous drops of this series were made to develop a cushioning system which could be relied on at impact velocities of magnitude close to the maximum expected for any one drop under actual field conditions. Since some of the drops under these conditions may be expected at the other end of the impact velocity

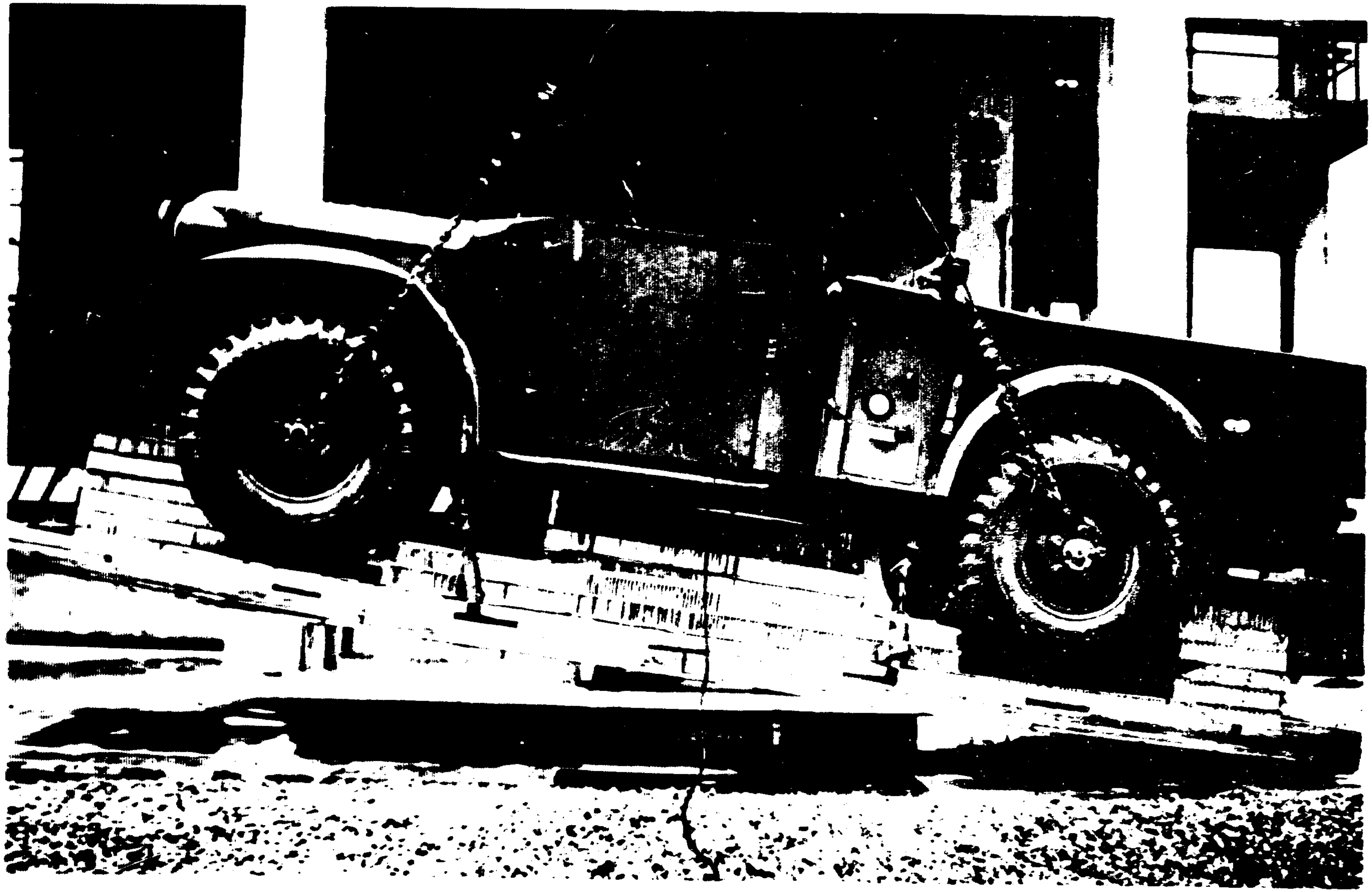


Fig. 6 System Rigged for Angled Drop

range, it was decided to test the cushioning system and drive-off capability at an impact velocity of 15 fps.

The system crushed uniformly to 25 percent and the ease with which drive-off was accomplished indicated that the truck could be driven off of the system without an actual drop being made. This would allow vehicles which had been prepared for airdrop, and then not dropped for some reason, to be deployed without the need for additional support equipment. It was later shown, by actual experiment, that the truck could be driven off of this cushioning system without a prior drop to crush the honeycomb.

The final system consists of nine cushioning stacks, one each under the winch, the front differential, the transmission, the side frame members, the gear reducer, the rear differential, and the rear frame members. See Fig. 7 and Table 2. In addition to these stacks, a honeycomb ramp system located between the front and rear wheels on each side is used to provide the drive-off capability. See Fig. 8. There are two loadspreaders used in the system, however these are easily fabricated from commercially available materials.

Measured accelerations and other data pertaining to all the drops are included in Table 3.

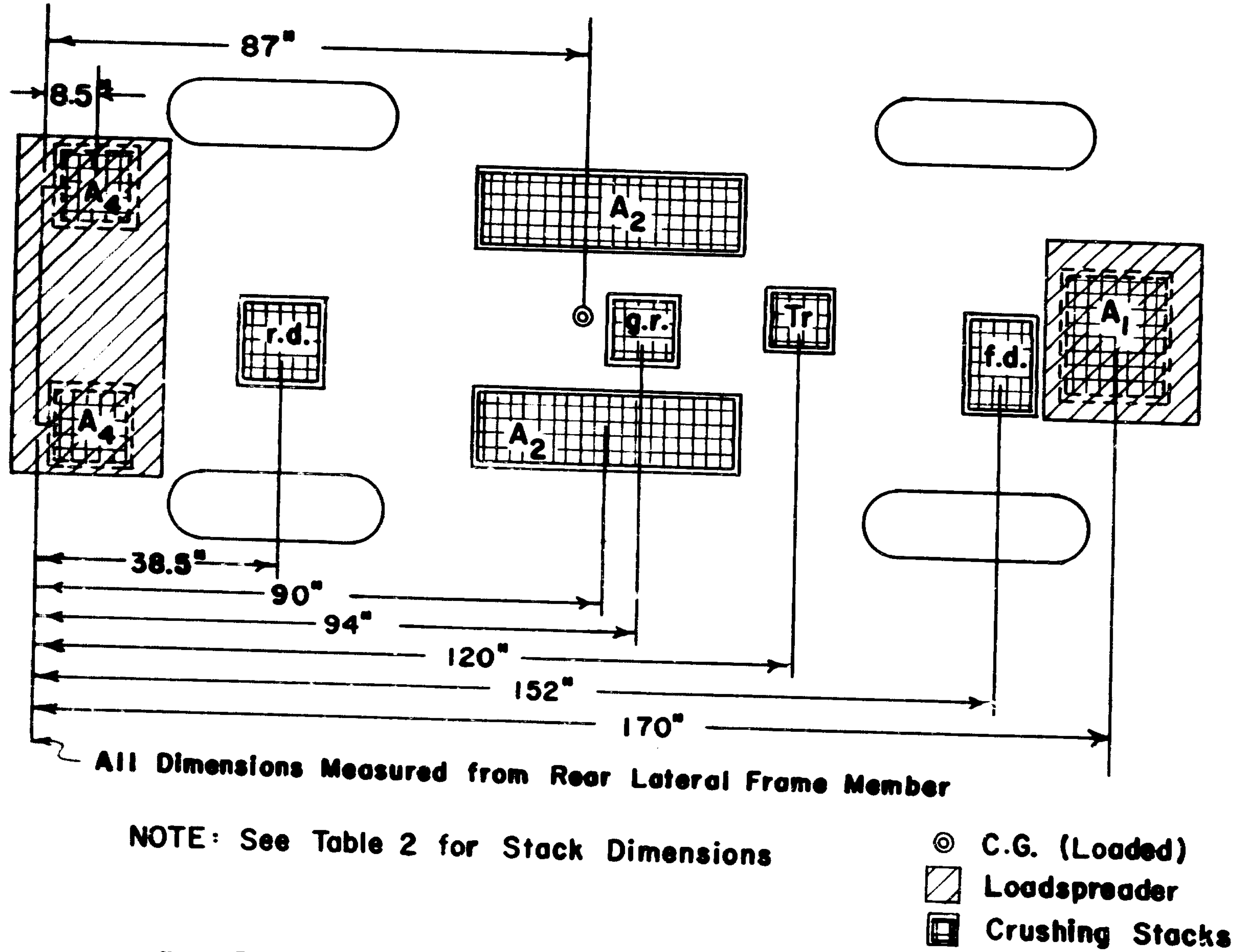


Fig. 7 Cushioning System for M37-11-67 through M37-15-67

TABLE 2

Drops M37-11-67 through 15-67

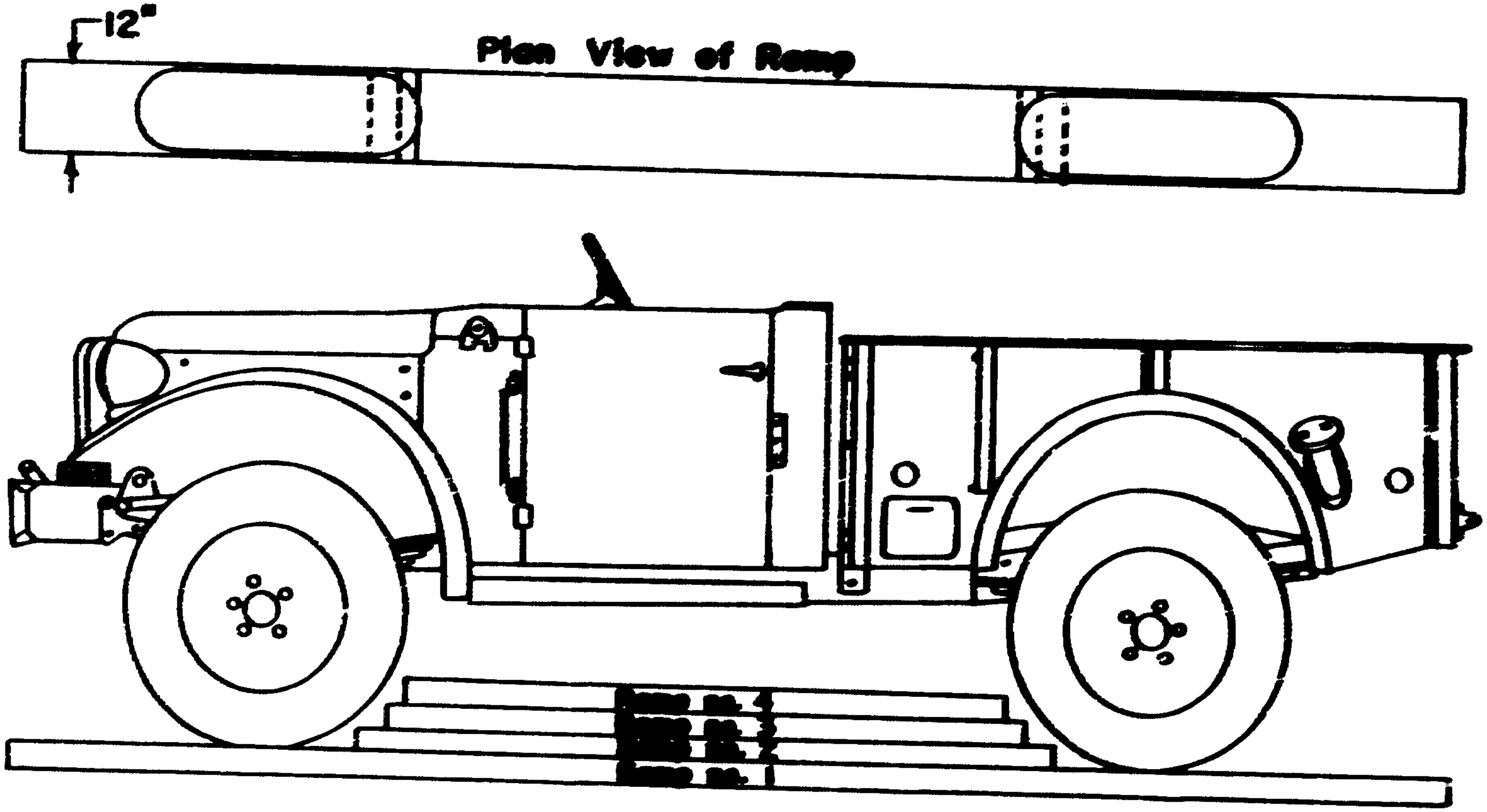
Design Acceleration 17.5g

Position (See Diagram)	Stack Area	Dimension W · L
A_1	2.64 ft^2	1.76'·1.5'
A_2	3.26 ft^2	0.9' ·3.62'
A_4	1.25 ft^2	1.1' ·1.14'
f.d. (front differential)	1.37 ft^2	1.37'·1.0'
g.r. (gear reducer)	0.85 ft^2	0.92'·0.92'
Tr (transmission)	0.57 ft^2	0.85'·0.85'
r.d. (rear differential)	1.37 ft^2	1.17'·1.17'

Total Height including Crushing Stacks = 69-1/2 inches

NOTE: There were no wheel stacks. However, the wheels were cushioned by the ramp system as seen in Fig. 8.

NOTE: M37-10-67 was made using the same stack placement as shown in Fig. 7, however, the stack areas were larger to provide for a 20g design acceleration.



Position	Size
Ramp # 1	144"·12"
Ramp # 2	90"·12"
Ramp # 3	84"·12"
Ramp # 4	80"·12"

Fig. 8 Ramp System for Drive-Off of M37 Truck

Drop Number	Area	Height	Design Accel.	Peak Accel.	Ave. Accel.	Impact Vel.	Vel. Change
						$\sqrt{2gh}$	$\int a dt$
M37-8-67	Winch	10'	30 g's	38.7	21.9	25.4	27.6
	Engine	"	"	No Record	No Record	"	No Record
	Rear	"	"	39.2	22.1	"	28.3
M37-9-67	Winch	10'	30 g's	36.8	22.7	25.4	28.7
	Engine	"	"	35.1	20.6	"	27.9
	Rear	"	"	37.0	21.9	"	28.3
M37-10-67	Winch	10'	20 g's	30.1	18.6	25.4	27.3
	Engine	"	"	No Record	No Record	"	No Record
	Rear	"	"	No Record	No Record	"	No Record
M37-11-67	Winch	10'	17.5 g's	28.6	13.6	25.4	28.6
	Engine	"	"	26.5	13.3	"	27.4
	Rear	"	"	No Record	No Record	"	No Record
M37-12-67	Winch	10'	17.5 g's	32.5	13.9	25.4	29.3
	Engine	"	"	28.6	12.8	"	31.8
	Rear	"	"	30.1	13.3	"	30.6
M37-13-67	Winch	10'	17.5 g's	28.7	12.7	25.4	26.5
	Engine	"	"	30.5	13.5	"	26.9
	Rear	"	"	31.0	13.8	"	27.2
M37-14-67	Winch	10'	17.5 g's	28.6	12.2	25.4	28.0
	Engine	"	"	32.0	13.9	"	28.2
	Rear	"	"	34.2	14.3	"	29.8
M37-15-67	Winch	3.5'	17.5 g's	28.8	12.7	15.0	18.6
	Engine	"	"	30.3	13.4	"	19.4
	Rear	"	"	30.7	13.7	"	18.1

TABLE 3
Acceleration Data

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13 ABSTRACT

Eight drops involving the M37 3/4-ton truck have been made in the velocity range from 15 to 28 fps, at design accelerations ranging from 17.5 to 30g. The cushioning system used for each drop is described and the damage sustained by the vehicle is discussed. It is concluded that the cushioning system developed in this series of tests provides adequate protection in the velocity range investigated and also provides a drive-off capability for the vehicle.

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
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Drive-off systems	8		6			
Cargo vehicles	9		7			
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14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

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